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THERMAL AND CFD ANALYSIS OF ENGINE FINS FOR DIFFERENT MATERIALS WITH VARYING SLOT SIZES AND SHAPES

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ABSTRACT

The engine is the heart of an automobile which is subjected to high temperature variation and thermal stresses. The high temperatures produced in the engine cylinder needs to be reduced for effective working of the engine. If the heat is not dissipated properly then it causes to development of the detonation and finally decrease the working efficiency hence, heat dissipation rate from the cylinder is one of the important task. These high temperatures are reduced by introducing the appropriate cooling mechanism air cooling, water cooling, oil cooling. An air cooled motorcycle engine release the heat produced by engine to the atmosphere through forced convection mode. Fins are provided on outer surface of the cylinder block. Fins are the extended surface which helps in dissipation of the heat generated in the engine. The heat dissipation depends upon the velocity of air, geometry of the fin and the thermal conductivity of the materials used. In this project an attempt is made to find out the thermal analysis and CFD simulation of cylinder block with fins for different materials like Al6061, Al2014, Al a380 and also changes are done in the design of fins to increase the heat dissipation rate. The changes made in the fins are increases the tip thickness and provides slots of different dimensions and shapes like rectangular slot, triangular slot, semicircular slot. The slot sizes are varied while keeping the fin size and the number of fins same. The 3D modelling is done on Creo 2.0software and the analysis part and CFD is done on ANSYS software for steady state condition. Results of the various analysis done shows that engine cylinder with aluminium alloy 2014 with semicircular slot of area 50 mm^2 dissipates more heat when air flows through the fins.

***KEYWORDS:** Slots, Heat flux, Thermal Conductivity, Fins, Creo, ANSYS & CFX*

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Original Article

1. INTRODUCTION

Engine is considered as the heart of any automobile which produce power to move the automobile. It converts chemical energy into mechanical energy by combustion of fuels. In this combustion process more amount of heat is produced due to burnt of air fuel mixture. The produced heat in this process almost 70% is lost into atmosphere and only the remaining 30% is successfully utilized. For the better performance of the engine a large amount of heat produced during combustion is to be dissipated. If this heat is not removed sufficiently and properly in time, it may cause problems in the engine and even engine will be ceased. Generally heat produced in the engine is dissipated by liquid cooling and air cooling. Because of high maintenance cost for the liquid cooled engines air cooled engine is preferred for smaller vehicles. In air cooled engines the fins play a vital role in dissipating the heat produced in the engine cylinder. Fins are the extended surfaces used to transfer the heat from engine surfaces to reduce metal surfaces. There are several factors affecting the heat dissipation rate of the engine cylinder such as

material used in engine cylinder manufacturing, geometry, shape, size, roughness etc. In this present research the effect of cylinder fin with thick tip and different sized slots of different shapes is analyzed and compared with the cylinder fin which is uniform with slots of different shapes. Along with the steady state thermal analysis CFD is done to know how the air flow affects the heat transfer of the engine cylinder. The development of design has been done in the Creo 2.0 software and the steady state thermal analysis and CFD have been performed in ANSYS 18.0.

2. AIM OF THE PROJECT

The main aim of the project is to design a modified IC engine fins by creating the thickness at the tip of the fin to make them non uniform and slots of various sizes and shapes are provided on the fins in a uniform manner. Then these designs are analyzed and compared with the engine cylinder with uniform fins and the analyzation is done with different materials. All these designs will undergo both steady state thermal analysis and CFD analysis in ANSYS. Steady state thermal analysis is done to determine the best material which will dissipate the heat more rapidly based on heat flux. CFD analysis is done to determine the effect of air on the fins so that we can find best engine design that removes more heat when subjected to air.

3. METHODOLOGY

The present work is carried out on thermal issues of automobile engine cylinder fins with slots on both uniform fin and non uniform fin. This investigation yields the heat flux and the temperature behaviour due to high temperature in the combustion chamber. In this project CFD simulation is also carried out to determine the effect of air which yields the best design of engine cylinder. The steps in performing the thermal analysis and CFD simulation are:

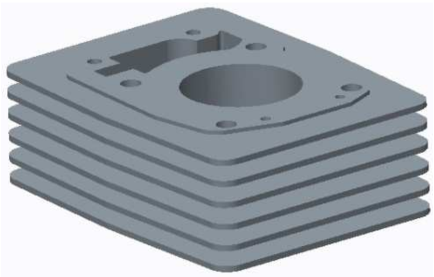
- Creating a solid model
- Geometry import in ANSYS Steady state thermal analysis
- Generating mesh
- Providing the boundary conditions
- Monitor the solver to achieve the solution and results visualization
- Geometry import to ANSYS CFX
- Generate the mesh and import the meshed component to preprocessor of CFX
- Provide all the boundary conditions in the preprocessor and go to solver to obtain solution
- Visualization of the results is done in postprocessor of the CFX in ANSYS

3.1. Design

In this project we have designed a cylinder fin body used in Honda Unicorn 150cc bike modelled in Creo 2.0. in this project we are using three different materials they are Al2014, Al6061, A380. In this project we designed engine cylinder with uniform rectangular fins and slots are made on the fins of different shapes and sizes. The slots of area 50mm^2, 75mm^2 and 100mm^2 are made in the shape of rectangular, triangular and semicircular shapes on the fins. And also designed the engine cylinder fins with thickness of 7mm at the tip and same slots mentioned above are made on these fins. The fin thickness (3mm) and the number of fins(6) of the actual engine cylinder will remain same.

Table 1

Materials	Thermal Conductivity (W/mK)	Specific Heat (J/KgK)	Density (Kg/mm^3)
Al 6061 (Si 0.4-0.81%, Fe 0.7%, Cu 0.15-0.4%, Mn 0.15%, Mg 0.8-1.2%, Cr 0.04-0..35%, Zn 0.25%, Ti 0.15%, Al 95.85-98.56%)	180	897	2700
Al 2014 (Cr 0.1%, Cu 3.9-5%, Fe 0.7%, Mg 0.2-0.8%, Mn 0.4-1.2%, Si 0.5-1.2%, Ti 0.15%, Ti + Zn 0.2%, Zn 0.25%, Al remaining)	192	880	3000
A380 (Si 7.5-9.5, Fe 1.3 Max, Cu 3.0-4.0, Mn 0.50 Max, Mg 0.10 Max, Balance Al)	109	963	2760



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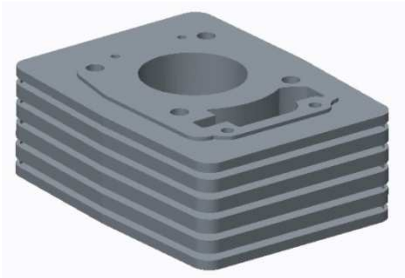

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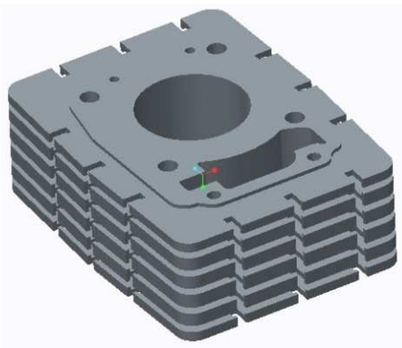

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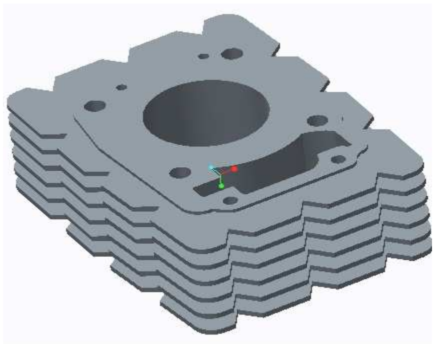

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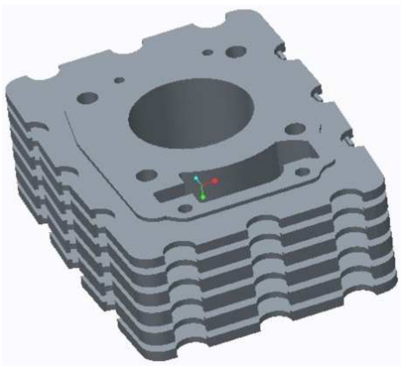
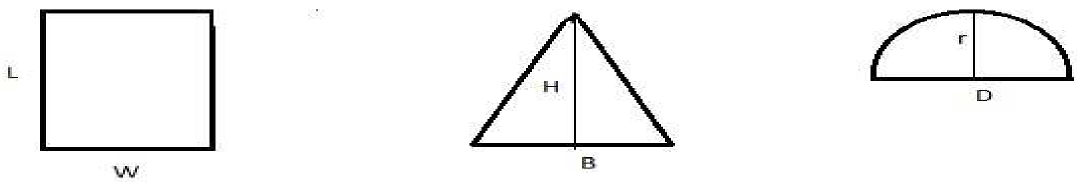


(e)

Figure 1: Design of Honda Unicorn Engine (a) Engine Cylinder with Uniform Fins and No Slots (b) Engine Cylinder Fins with Thickness at the Tip (c) Engine Cylinder Fins With thick Tip and Rectangular Slots of Area 50 mm^2 (d) Uniform Fins with Triangular Slots of Area 75 mm^2 (e) Thick Tip Fin with Semicircular Slot of Area 100 mm^2

3.2. Slot Area Calculation

In this project three types of slots are made on the fins to determine the effect of these changes in geometry on the heat transfer. The slots are of same area but different in shape. The slots are made in rectangular, triangular and semicircular shapes of 50mm^2 75mm^{2}100mm^2 of areas. Reason for taking the same slot area is to study the effect of different shaped slots on the heat transfer. Based on these areas we need to calculate the width of the rectangular slot, base of the triangular slot and radius of the semicircular slot.



- Length(L)=Height(H)=10 mm
- Area of rectangle= L*W=50 mm^2

  10*W=50 mm^2 W=5 mm
- Area of triangle= 1/2*B*H= 75 mm^2

  1/2*B*10=75 mm2 B=15 mm
- Area of a semicircle= $\pi r^2/2$=100 mm^2

  r2 =200/π

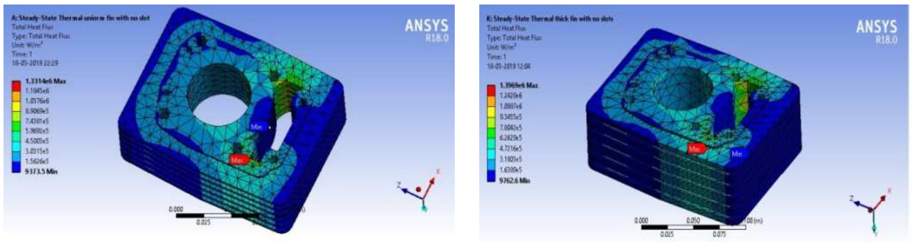
  r =$\sqrt{(200/\pi)}$ r= 7.97 mm

3.3. Analysis Setup

In this project we have done steady state thermal analysis and CFX to determine the best material and design which increases the heat transfer and these two analysis were carried out in ANSYS 18.0. The created geometry is imported into steady state thermal analysis and coarse mesh is generated which is program controlled. Our next step is to apply the boundary conditions we provide the temperature of 800^{0}C inner side the cylinder of the engine. Convection takes place on the fins and we give values for the convection parameters like film coefficient and ambient temperature as 25W/m^{2}K and 25^{0}C respectively. For CFD analysis we use CFX in ANSYS. In this analysis we have studied the effect of air on the cylinder with and without fins by giving the constant input parameter like the air velocity and the pressure. In this analysis in geometry section an enclosure is made around the body which we want to study the effect of air and then name all the sections and it was meshed and this was imported into the pre-processor of CFX. In this pre-processor all the boundary conditions are like inlet velocity of air i e. 20 m/s and pressure at the outlet as 1 atm. The reason behind doing this analysis is to find out which design removes more heat for this observation. The air with velocity 20 m/s is made to pass on the cylinder fins of temperature 500^0 C and observe the temperature distribution at the outlet. The change in the temperature distribution allows finding out which design removes more heat when exposed to air stream.

3.4. Visualisation of Results

The heat flux contour of the different surfaces of engine cylinder fin can be predicted by computational analysis. The heat flux over the convective surface area of the engine fin having slots of different shape and sizes are shown in the figure 2.



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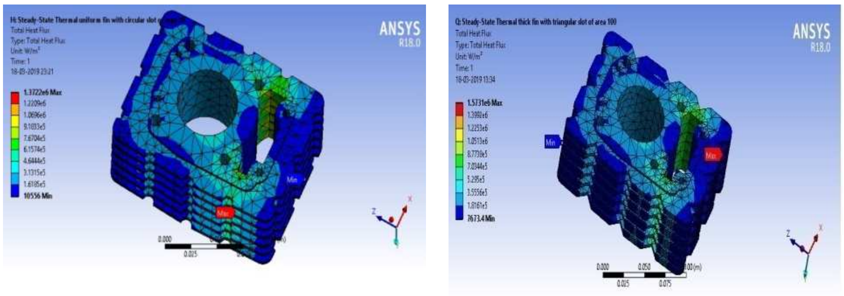
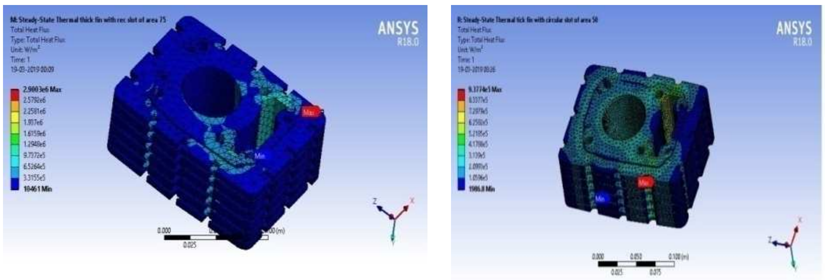


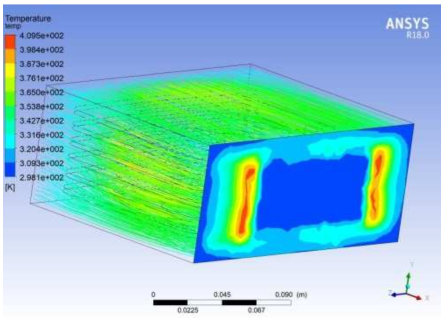
(c) **(d)**

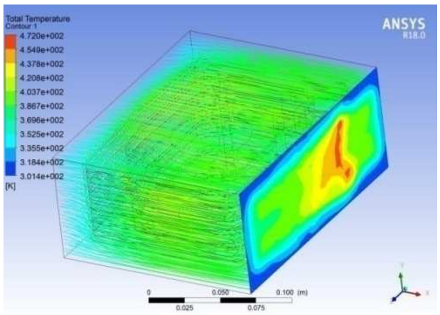


(e) **(f)**

Figure 2: Heat flux Contour of (a) Honda Unicorn Engine Fins with Uniform Thickness of Aluminium Alloy 2014. (b) Tip Thick Fin of Aluminium Alloy 6061 with no slots (c) Uniform Fin of Aluminium Alloy 2014 with Semicircular Slot of area 50 mm^2. (d)Tip Thick Fin of Aluminium Alloy of 6061 with Triangular Slot of Area 100 mm^2. (e) Tip Thick Fin of Aluminium Alloy 2014 with Rectangular Slot of Area 75 mm^2. (f) Tip Thick Fin of Aluminium Alloy 2014 with Semicircular Slot of Area 50 mm^2

The total temperature contour at the outlet of the enclosure in CFD analysis which gives the best design for air to flow through it and take maximum amount of heat from the cylinder fins are shown in figure 3.





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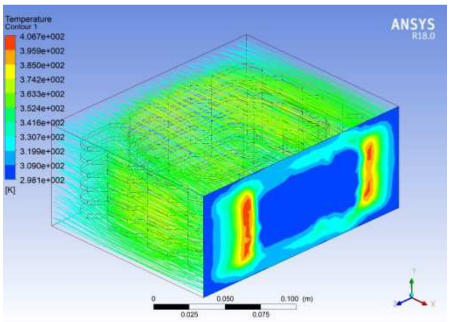

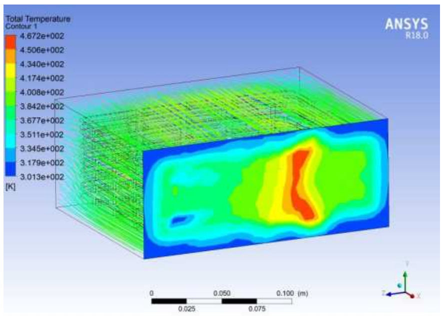

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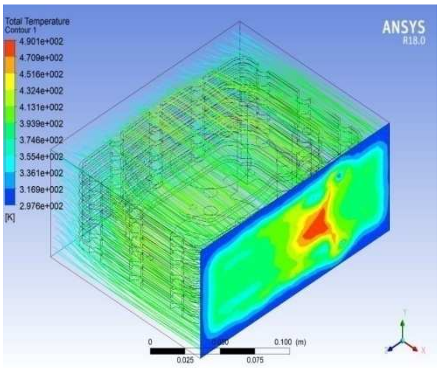

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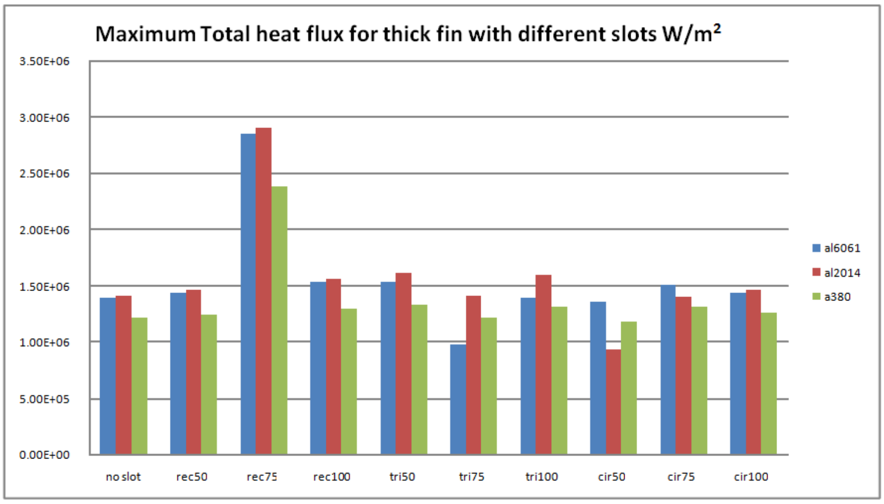
Figure 3: The Temperature Contour for CFD Analysis of Engine Cylinder with (a) Uniform Fin with No Slots. (b) Thick Tip Fin with no Slot. (c) Uniform Fin with Triangular Slot of Area 100 mm^2. (d) Thick Tip Fin with Rectangular Area of 50 mm^2. (e) Thick Tip Fin wit Semicircular Area of 50 mm^2

4. RESULTS AND DISCUSSIONS

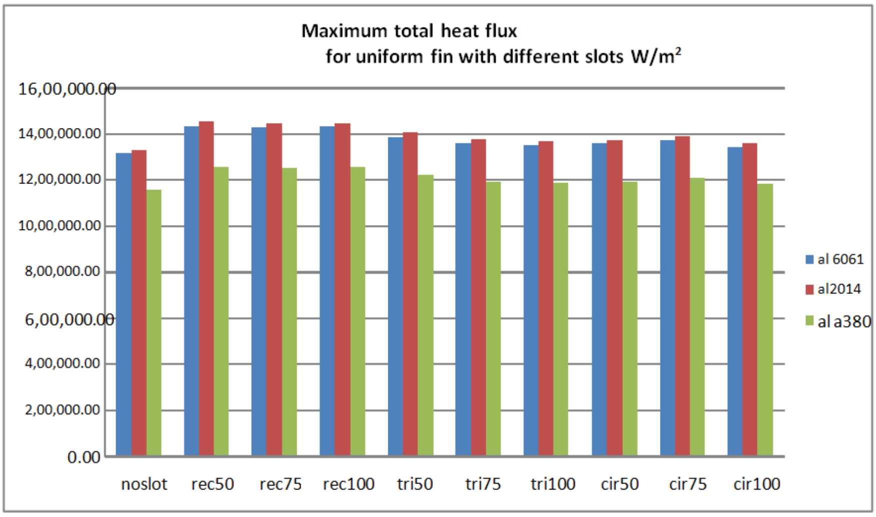
We have done the thermal analysis and CFD analysis of the engine cylinder with uniform fin and thick tip fin by varying material, slot shapes and sizes and compared the results of both uniform fin and thick tip fin. We have taken three materials for analyzing which material is best suited to dissipate heat from the engine.

The slots made on the fins are of area 50 mm^2, 75 mm^2 and 100 mm^2 in rectangle, triangle and semicircular shapes. With this we can observe that the change in the shape of the slot of same area changes the result of analysis. When we slot the uniform fin the weight of the engine cylinder gets decreases but heat transfer decreases when slot size is increasing. When we made slots on the thick tip fin the heat transfer rate increases with the increase in the thermal conductivity of the material. We made air to pass through the fins at speed of 20 m/s from front side of the engine and temperature contours are taken at the backside of the engine and compared the results of uniform fins and thick tip fins. We

observed that the thick tip fins makes air to flow back side of the engine and the slots makes air to move through the fins and carries more heat from the fin surfaces. When we try to increase the slot size the amount of heat carried by air decreased. The heat flux through the engine is compared for different material, fins are shown in figure 3 and temperature at the backside of the engine is compared shown in figure 4.

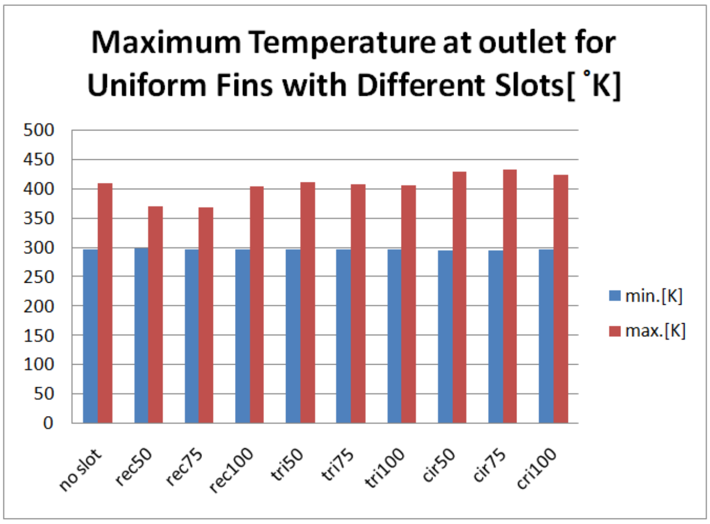


(a)



(b)

Figure 3: (a) Comparison of Maximum Total Heat Flux of Thick Tip Fin for Different Materials. (b) Comparison of Maximum Total Heat Flux of Uniform Fin for Different Materials



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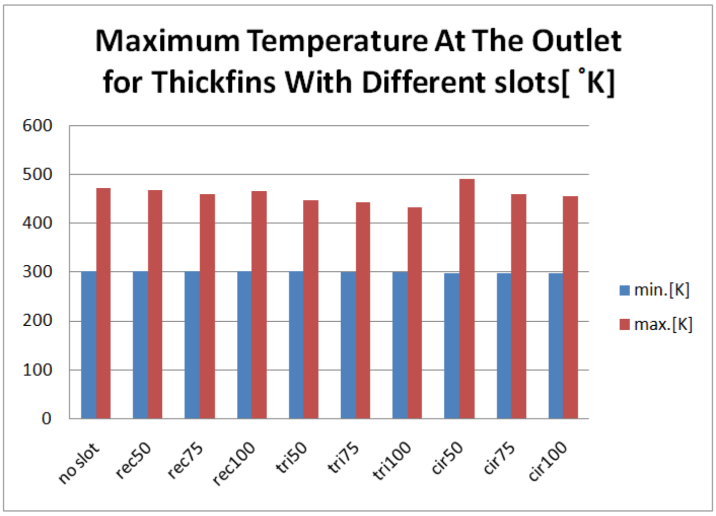

(b)

Figure 4: (a) Graph for Comparing the Inlet and Outlet Temperature of Uniform Fins with Different Slots. (b) Graph for Comparing the Inlet and Outlet Temperature of Thick Tip fin with Different Slots

5. CONCLUSIONS

In this present work thermal analysis and CFD analysis of engine cylinder with uniform fins and thick tip fins were performed with making slots of different shapes and sizes and various material to find out which material and design best for dissipation of heat from the engine. For this study Honda unicorn 150 cc bike cylinder block is considered and modelled and the analysis is carried out in ANSYS. After observing the results of thermal analysis the material with higher thermal conductivity possessing more heat transfer in thick tip fins. By observing the CFD analysis results, the thick tip fins with slots of small size shows better results. From all the results of thermal analysis and CFD analysis it is to be concluded that engine cylinder with thick tip fin with circular slot of area 50 mm^2 of aluminium alloy 2014 had the better heat transfer rate.

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